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THE DIVISION PUMPING STATION AT CLEVELAND, OHIO, AND ITS OPERATION[1]

By J. N. H. Christman[2]

Actual work to give the City of Cleveland its first water department was started in the year 1854, when the population of the town was approximately 30,000. The installation consisted of a pumping station on Division Avenue equipped with two Cornish pumps, each having a capacity of 4,000,000 gallons per day. The water for these pumps was drawn through an inlet pipe 50 inches in diameter, situated 300 feet west of the old river bed and extending out into the lake 300 feet, connecting at the shore with a 5-by-4-foot brick aqueduct. The discharge from these pumps was carried to a reservoir of 6,000,000 gallon capacity and 158 feet elevation, on Franklin Avenue at Kentucky Street. The piping system consisted of 13 miles of pipe of various sizes. The cost of this water supply system was $513,600 and it was considered ample for 200,000 inhabitants and adequate for the next 50 years. Water was first turned into the mains on September 19, 1856.

Work was begun on Cleveland's first lake tunnel in 1869, when the population of the town was about 86,000. This was a 5-foot tunnel which was built at the point of the old aqueduct at the lake shore to an intake crib located in Lake Erie 6600 feet from the shore and approximately the same distance west of the Cuyahoga River. The capacity of this tunnel was estimated as 40,000,000 gallons per day. The salient feature in the construction of this tunnel was the change in the location of the water intake from about 300 feet from the shore to a mile and a quarter. This change of water inlet was necessitated by the pollution of the shore water due to the rapidly growing town. In the meantime Division Station was enlarged by building a new boiler and engine house. Two 10,000,000-gallon pumping engines were erected in the new building and additional water mains were laid throughout the City. The total pumping capacity of the station was now 28,000,000 gallons per day. This was not actual pumping capacity, however, because it was discovered that when either of the new 10,000,000-gallon engines was in operation, the two Cornish pumps could not be run on account of the suction of the large engine lowering the water in the wells so that the suction of the Cornish pump was uncovered.

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About 1876 the mode of supply to the consumer was changed. Water was pumped directly into the mains, with the reservoir floating on the line and being used for pressure regulating and water supply equalizing purposes only, taking the surplus pumpage and making up deficiencies in pumpage instead of receiving the water directly from the engines and supplying the consumers by gravity. About six years later the water consumption had increased to such a point, due to growth of the City, that work was started on the new low-service reservoir at Fairmount Station, and the first high-service reservoir at Kinsman Road. Additional buildings and pumping machinery were installed at Division Station, and about 92 miles of feeder and distributing mains were laid. These improvements established the low and high-service pressure zones. With the city's rapid growth and the consequent increase in water consumption, the capacity of the 5-foot tunnel was insufficient, so in 1888 work was begun on the second lake tunnel. This was a 7-foot diameter tunnel extending from the old West Side intake crib to Division Avenue Station. Its capacity was estimated at 110,000,000 gallons per day, which with the 5-foot tunnel gave the City a capacity of 150,000,000 gallons per day. The pumping capacity from Division Station had been, in the meantime, increased to 70,000,000 gallons per day.

The population in 1891 was 272,000. This shows how far the City exceeded the growth expected at the start of the waterworks system in 1854, when it was thought that the little 50-inch lake inlet tunnel would supply the City for 50 years.

The addition of boiler rooms and engine rooms to Division Station necessitated by the increase in water consumption made the station very unwidely, so that in 1896 it was decided to provide the City with a duplicate system of water supply, and work was begun on the 9-foot east-side tunnel. Accidents delayed the completion of this until 1903, and in the meantime the new Kirkland Station had been completed and the necessary water mains laid, so that on

February 11, 1904, Kirkland Station went into service and the old Division Station shut down until the west-side tunnels could be extended further into the lake.

Immediate extension of the west-side tunnels was intended upon the completion of the east-side system. A new tunnel was to be built from Crib 4, 16,000 feet northwesterly to a new intake crib to be located four miles from shore. In the year of 1901, while the east-side tunnel was under construction, a radical change was made in the method of delivering water to consumers by metering all services. Prior to this date, water for manufacturing, commercial and other business purposes was the only water metered, being only 6.42 per cent of the total water consumed. This small percentage, however, of metered service brought in 42 per cent of the total revenue. The effect of this general application of meters was to so reduce the consumption of water as to defer the need of extending the west-side tunnels for the time being.

The daily average consumption in 1901 was 69,600,000 gallons, equal to 170 gallons per capita per day. This consumption steadily decreased as the number of meters installed increased, until 1908 when the average daily consumption was 52,000,000 gallons. In 1909 the daily consumption was 52,800,000 gallons, equal to 97.8 gallons per capita per day. In other words the daily per capita consumption, by metering all the service, had fallen from 170 gallons in 1901 to 98 gallons in 1909, the population in the meanwhile having increased from approximately 396,000 to 540,000. From then on, the rapid growth of the city overbalanced the saving effected by the meter system, and the daily consumption again began to increase. It was therefore decided to proceed with the work of extending the west-side tunnels.

The plans for the work provided for 16,000 feet of 10-foot tunnel running northwesterly from the junction of the old 5- and 7-foot tunnels at Crib 4 to the new intake crib to be located four miles from shore. Bids for the work were received three different times and rejected in each instance as being too high. After the receipt of the last bids, the lowest which was $1,068,000, exclusive of the intake crib, for which a separate contract was let, the city decided to build the tunnel by direct labor. In the meantime, the crib for the intake shaft had been built and placed in position in Lake Erie.

Preliminary work on the tunnel was begun in May, 1913, which consisted of filling in a swamp on Whiskey Island, building a roadway, and boat landing on the same, installing a storehouse, power plant, etc. In March, 1913, a disastrous flood carried such an amount of silt into the lake that it remained in suspension for two or three months. The turbidity remained for so long after the flood that the Mayor of the City became convinced that a filtration plant was necessary, and a commission was appointed to investigate and recommend the type of filter plant which was best suited for Cleveland's needs. On January 27, 1914, actual work was begun on the filter plant in accordance with the commission's recommendations. The entire work, with the exception of the final examination and test of the structure, was completed by February, 1916. The building of the filtration plant necessitated an entirely new station at Division Avenue with the necessary piping changes for the same.

Investigations at the time the city was completing the east-side tunnel by direct labor, and expert testimony in a lawsuit occasioned by the City taking the tunnel work away from the contractor, recommended that the tunnel should be unwatered as soon as possible and repaired if it was to be used further. This was the reason for the first filtration plant being built on the west side. When it was finally decided that filtration of the city water was necessary, plans were laid to proceed as follows:

1. A filtration plant of 150,000,000 gallons daily capacity to be built next to the Division Avenue pumping station.
2. To entirely rebuild the old Division Avenue pumping station.
3. To install three new service pumps, overhaul and rebuild three old vertical triple-expansion crank and fly-wheel pumps at the station, and to move the 30,000,000 gallon DeLaval turbine pump from Kirkland to Division Station.
4. To install three low-lift pumps with a total capacity of 260,000,000 gallons for furnishing the filter plant with raw water from the tunnels.
5. To install the necessary water mains.

All this work was to be done in the shortest possible time. The Kirkland pumping station was then to be shut down and the east-side tunnel unwatered, examined, and repaired, if necessary. While Kirkland was shut down, a new filter plant should be built in connection with it.

The final plans of the new station showed a T-shaped ground plan layout. The main engine room is approximately 226 by 73 feet, inside dimensions. The north pavilion or low-lift pump room is on the north end of the main engine room and is approximately 148 by 52 feet, inside dimensions. The boiler room adjoins the east side of the main engine room and is approximately 100 by 96 feet, inside dimensions.

Bids were received, contracts let and actual work was started in the fall of 1914. Three new service pumps were purchased, two of 25,000,000 gallons capacity at 250 feet head for low-service pumping, and one of 20,000,000 gallons capacity at 400 feet head for first high service pumping. The Allis-Chalmers Company was the successful bidder for the new pumps, and also for the rebuilding of the three old pumps, which consisted of one 20,000,000-gallon low-service engine called Allis No. 1; one 20,000,000-gallon low-service called Kilby No. 1, and one 10,000,000-gallon first high-service engine called Holly No. 1. The rebuilding of these three old engines was necessitated by the decision to use 200 pounds steam pressure and 100° superheat.

The Dravo-Doyle Company was awarded the contract for furnishing three low-lift centrifugal pumps, two of 100,000,000 gallons per day capacity and one of 60,000,000 gallons capacity, each capable of delivering their ratings at 50 feet total head.

Foundations for eight 500 horsepower boilers were put in the new boiler room, but only five were purchased. These are four-pass Stirling boilers furnished by The Babcock & Wilcox Company. A sixth boiler had been installed since, but to date has not been put on the line. All boilers were equipped with 6-retort Riley stokers and each boiler has its individual stoker engine and fan. There is also an individual coal weighing hopper, recording flow meter, 3-in-1 draft gage, recording pyrometer, etc., for each boiler.

Overhead storage bins of approximately 1080 tons capacity were provided. These are served by two Link-Belt conveyors which carry the coal from the outside hopper under the railroad track to the bins. These two conveyors also handle the ashes carrying them to a bin over the railroad track and permit an easy removal of the ashes in a standard coal car.

Two stacks, each 228 feet high by 9 feet diameter, carry away the products of combustion.

Two Kerr-Worthington centrifugal pumps and one Epping-Carpenter horizontal compound duplex pump were provided for boiler feeding. These pumps are supplied by a 4000 horsepower Cochrane open feed water heater. A Moore-Manistee centrifugal pump has since been installed.

The necessary piping was provided for and in addition test condensate and exhaust pipes were carried to the feed water heater, which was so fitted that a complete individual test could be run on any pumping unit or boiler without disturbing station operation.

TABLE 1

The following guarantees were made and results obtained on duty trials on the different pumping units

ENGINE	GUARANTEED DUTY PER MILLION B. T. U.	TEST DUTY PER MILLION B. T. U.	TEST DUTY PER 1000 LBS. STEAM
Service pumps:			
Allis No. 1 (rebuilt)..........		171,319,822	207,837,683
Allis No. 2....................	170,000,000	171,123,384	204,767,090
Allis No. 3....................	170,000,000	171,279,745	206,202,770
Kilby No. 1 (rebuilt).........		157,619,666	189,895,399
Holly No. 1 (rebuilt).........		169,610,398	201,580,840
Allis No. 4....................	170,000,000	173,802,905	211,540,084
Low-left pumps:		*Operation*	
DeLaval No. 2..............	153,700,000	Bleeding	154,294,000
	127,825,000	Non-bleeding	128,319,000
DeLaval No. 3 and 4........	160,937,000	Bleeding	169,231,000
	130,250,000	Non-bleeding	132,479,000

A small 100 kilowatt unaflow engine generator set was installed, which supplies the station and filter plant with necessary current. The municipal electric light current was brought in as a standby.

Machine tools for routine repair work only were provided.

The station was completed in 1917, but trouble was experienced with the clear water reservoir which provides suction for service pumps. As the suction of the two first high-service pumps was connected into the low service main from Kirkland station, it enabled the 10,000,000-gallon Holly to be started in June, 1917. The completion of repairs to the clear water basin permitted the remainder to be put in service and the last engine, Allis-Chalmers No. 4, was put on the line February 2, 1918.

Duplex condensate pumps, float controlled, replaced the plunger condensate pumps direct driven from the air pump on all the low lift pumps.

All pumps and boilers either met or exceeded their guarantees so there were no controversies on the subject. (See table 1.)

Test duties are actual results, uncorrected for superheat.

Guaranteed duties are the averages of guarantees for 50° and 70° circulating water.

Average duties figured giving duty at 100 per cent rating twice the weight of duties at 60 per cent and 115 per cent.

Average of bleeding and non-bleeding duties figured giving bleeding duties 7 points and non-bleeding duties 3 points.

The cost of each of these three low lift units was $41,700.

An interesting feature in connection with the triple expansion pumps is the cost of the different units as shown in table 2.

TABLE 2

Cost of triple-expansion pumps

NAME	NUMBER	COST	CAPACITY M. G. D.	DATE ERECTED
Holly	1	$115,700	10	1901
Allis	1	64,350	20	1899
Kilby	1	131,500	20	1902
Allis-Chalmers	2	84,500	25	1915
Allis-Chalmers	3	84,500	25	1915
Allis-Chalmers	4	90,000	20	1915

Guaranteed efficiencies of boiler, furnace and grate and test results were as follows:

Rating	100	150	200.0
Guaranteed efficiency	77	75	70.0
Test Efficiency	79	81	72.5

As the superheat obtained was such that the steam temperature was nearly 600°, to which the vertical triple expansion engine builders objected, 13 of the 40 superheater tubes were removed from each boiler, leaving about 319 square feet of superheating surface from which the desired steam temperature of 500° is obtained.

The five boilers, including brickwork, cost $43,514 and the stokers $19,000. This figures out about $25 per boiler horsepower installed, which is less than 50 per cent of what was paid per boiler horsepower for the last installation at this station.

Throughout a year's operation, the boiler-room efficiency averages very close to 75 per cent and table 3 shows results obtained for the year 1920 with coal costing $4.60 per ton at the stations.

During 1920, 22,215,000,000 gallons were pumped into the low-service mains against an average head of 191.4 feet, and 7,497,000,000 gallons were pumped into the high-service mains against an average head of 367.8 feet. This total is 57.8 per cent of all the water pumped from the lake, and it cost $11.43 per million gallons to pump it.

The station showed an average overall duty of 117,000,000 foot-pounds per 100 pounds of coal based on water handled and coal consumed, no corrections being made for steam supplied the filter plant, some of which is live steam and some exhaust. In the summer, with no heating load on the plant and a maximum demand on the pumps, a duty of 126,500,000 foot-pounds is reached.

TABLE 3

Results of boiler room operation, 1920

Total steam generated	514,635,380.00 pounds
Total coal consumed	60,909,615.00 pounds
Actual evaporation as fired	8.46 pounds
Cost of coal per 1000 pounds steam	28.200 cents
Operating labor cost per 1000 pounds steam	8.620 cents
Routine repairs, labor cost per 1000 pounds steam	1.306 cents
Routine repairs, material cost per 1000 pounds steam	2.894 cents
Total cost per 1000 pounds steam	41.020 cents

In order to keep the station equipment at its highest possible efficiency, the station chief works in conjunction with the mechanical engineering department. Check tests are run from time to time, gages and venturi meters are continually checked, and any piece of apparatus becoming unsuitable or showing undue wear or breakage is replaced by something better, if possible.

Upon completion of the installation of the new 20,000,000 gallon per day DeLaval turbine, the station will have a 50,000,000 gallon per day capacity for first high-service pumpage. There is at present 90,000,000 gallons per day capacity for low-service pumpage and room for one more pump. The low-service demands are such that a new pump will probably be purchased in the near future. After its installation, Division Station will have reached its limit in capacity.

A brief description has been given of the Division Station of the past, but what the Division Station in the future will be, cannot be determined now, as obsolescence determines pumping station life. All the conditions in the stations are not ideal. If the station were rebuilt now, some changes would certainly be made, but at the same time it is felt that it is a very efficient station, which will do good work for many years to come.